(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification⁷: H05G 2/00

(21) International Application Number: PCT/GB02/02063

(22) International Filing Date: 3 May 2002 (03.05.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0111204.4   8 May 2001 (08.05.2001)   GB

(71) Applicant (for all designated States except US): POW-
ERLASE LIMITED [GB/GB]; Imperial House, Link 10,
Napier Way, Crawley, West Sussex RH10 9RA (GB).

(72) Inventors; and
(75) Inventors/Applicants (for US only): TAYLOR, Alan
[GB/GB]; Powerlase Limited, Imperial House, Link 10,
Napier Way, Crawley, West Sussex RH10 9RA (GB).
KLUG, David [GB/GB]; Powerlase Limited, Imperial
House, Link 10, Napier Way, Crawley, West Sussex
RH10 9RA (GB). BARNETT, Christopher [GB/GB];
Powerlase Limited, Imperial House, Link 10, Napier Way,
Crawley, West Sussex RH10 9RA (GB). MERCER, Ian
[GB/GB]; Powerlase Limited, Imperial House, Link 10,
Napier Way, Crawley, West Sussex RH10 9RA (GB).

(74) Agents: ROBERTS, Gwilym, Vaughan et al.; Kilburn &
Strode, 20 Red Lion Street, London WC1R 4PJ (GB).

(81) Designated States (national): AE, AG, AL, AM, AT, AU,
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,
CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,
GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC,
LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW,
MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG,
SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ,
VN, YU, ZA, ZM, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR,
GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent
(BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR,
NE, SN, TD, TG).

Published:
— with international search report
— before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments

For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.

(54) Title: HIGH FLUX, HIGH ENERGY PHOTON SOURCE
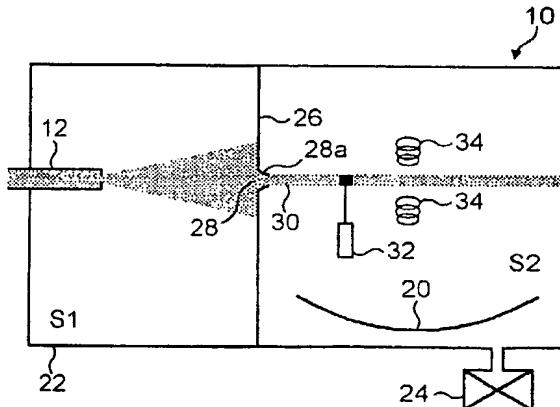
(57) Abstract: A high energy photon source for generating EUV radiation comprises a nozzle emitting a supersonic stream of
source material, a laser or electrical/magnetic pre-ionisation mechanism and a laser or electrical/magnetic excitation mechanism and
a skimmer plate between them providing a collimated high density beam of source material for excitation.

1

High Flux, High Energy Photon Source:

The invention relates to a high flux, high energy photon source, in particular a pulsed plasma source.

5

It is desirable in various applications, to produce photons with wavelengths in the extreme ultra-violet (EUV) range, in the region of around 1-50nm. One such application, for example, is semi-conductor lithography where increasing demands on resolution require shorter wavelengths.

10

Various pulsed plasma sources are known for producing EUV. These can be divided into two basic types, electrical/magnetic sources sometimes termed discharge produced plasma (DPP) sources embracing electrical excitation of the plasma using, for example, discharge, capacitative or inductive type systems and laser produced

15   plasma (LPP) sources. In either case an appropriate pulse applied to a material, usually a target or working gas, and creates a plasma from which EUV radiation is generated.

Various problems exist with known systems, however, including low efficiency – in

20   the region of 0.25% for electrical/magnetic excitation and 0.5% for LPP (or about 1.5% for LPP with solid/liquid targets). This means that power inputs of 25-150kW and 5-75kW respectively are likely to be required for lithographic production systems.

Attendant to that, high heat loading on the supporting system, bearing in mind that the

temperatures generated in the plasma can be of the order of hundreds of thousands of

kelvin in order to reach the optimum temperature for the generation of the desired

EUV wavelength, and the creation of large amounts of debris – that is, high velocity,

5   high energy matter created as the plasma expands - from the plasma and from

secondary damage/heating are highly problematic for production tools. Scaling LPP

and electrical/magnetic excitation to production levels is problematic not only in terms

of heating and debris, but also vis a vis dose control, cost, reliability and efficiency. In

particular, higher conversion efficiencies could mitigate the thermal and debris issues.

10

Debris is a significant problem in both LPP and electrical/magnetic excitation systems

due to the need for a large and expensive collection optic to share the vacuum space in

order to collect a high solid angle of emission. Primary debris from the plasma or

secondary debris from chamber components significantly reduce the useable lifespan

15   of such an optic. Heat loading is a problem in that the chamber components will distort

and possibly be damaged if sufficient cooling is not available. Moreover the large

collection optic has a very precise shape, and heating easily distorts it beyond usability

and/or causes direct damage to the coating.

20   Cost of ownership is also a serious problem. Although LPP applied to solid/liquid

targets currently holds out the possibility of higher conversion efficiencies than

electrical/magnetic excitation, the capital cost of the lasers needed for a production

level tool is expected to be much higher than that associated with electrical/magnetic

excitation. It is not clear which route offers the most attractive solution in this respect,

even if the problems of debris and heating can be overcome.

5   One known electrical/magnetic excitation system described in US 6,084,198

comprises an electrode column in which a plasma sheath is formed. The plasma

sheath exits the column and forms a pinch at the end. Gas at the pinch generates EUV

photons. The arrangement, however, requires close contact between the working

electrodes and the working gas with concomitant issues of electrode damage.

10   Moreover it is difficult to control plasma parameters such as size, shape and density

and thereby maximise the conversion of electrical energy to the required wavelength

of EUV radiation.

US 6,084,198 further discloses a plasma initiator in the form of spark plugs

15   surrounding the electrode column, but this arrangement is inflexible and does not

allow much variation in the operating parameters of the working gas/gasses. A further

problem is that the spark plugs themselves are exposed to the plasma created and that

additional components can be required to avoid damaging re-strikes.

20   Another electrical/magnetic excitation system is described in US 6,031,241 in which a

discharge is formed in a capillary to create a plasma from material introduced into the

capillary. This arrangement suffers from the further problem that the plasma is created

4

within the capillary which must therefore be treated to resist the extreme conditions it
is subjected to. Maintaining capillary integrity is difficult, and there is a limit to the
EUV yield that can be achieved in a single capillary.

5   A known arrangement is illustrated in Fig. 1 and designated generally 10. A gas,
preferably an inert gas such as Xenon is fed at high pressure through nozzle 12. The
gas expands supersonically into a cone 14 on exiting the nozzle 12 and is subjected to
excitation by a laser 16. A plasma is created which emits EUV radiation collected by
collector 20 which may for example be a parabolic reflector and channelled therefrom
10   for the desired use, for example in semiconductor lithography.

According to this arrangement the use of a suitably shaped nozzle and supersonic
beam of gas, produces a high gas density. If for example an inert gas such as Xenon is
used, clusters of gas atoms are formed which helps to maintain a high local gas density
15   and it thought to assist EUV generation However various problems arise with the
system. Because of the rapid expansion of the gas cone 14 the laser 16 must be
focused as close as possible to the nozzle 12 to maintain an acceptable energy density
in the plasma. As a result the nozzle 12 is at risk of damage because of its proximity
to the plasma, and the arrangement as a whole is physically constrained.
20

Yet further, the expansion of the gas in a cone away from the nozzle gives rise to
debris filling the chamber in an broadly expansive beam. Despite the use of an inert

5

gas as the source gas this can be damaging to the components of the system and in

particular the collector mirror, which is at risk of physical damage from collisions with

more massive particles, and chemical damage such as oxidisation. This in turn places

constraints on the overall chamber design.

5

Yet further the gas density is not constant across the cone 14 as a result of which the

laser pulse may be absorbed by the lower density periphery of the cone, providing

unsatisfactory penetration to the high density centre of the source gas cone.

10   It is known in electrical/magnetic excitation systems that in order to improve the

efficiency and stability of EUV generation, additional electrodes or coils can be

introduced to pre-ionise source material by electrical/magnetic excitation. Such pre-

ionisation is known to allow creation of a more stable and well defined plasma as well

as enhanced control of the initial conditions, in particular reducing fluctuation between

15   pulses and enhancing dose control. However the pre-ionisation electrodes are

exposed to potentially damaging conditions. Moreover, spatially smooth pre-

ionisation is a necessary condition to avoid hot or cold spots in the final plasma. Such

variations in temperature reduce the efficiency for emission in the required spectral

bandwidth and therefore limit the effectiveness of the device.

20

Background pressure in known systems can be detrimental as it can give rise to self-

absorption, the source gas surrounding the gas cone absorbing some of the EUV

6

radiation before it reaches the collector, reducing the efficiency of the system. In

order to reduce the problem of self-absorption in known capillary systems, differential

pumping is used. A significant pressure gradient is thus maintained in the known

systems requiring costly and high maintenance pumps.

5

According to the invention there is provided a high energy photon source comprising a

source material emitter arranged to emit a stream of source material, an excitation

component downstream thereof arranged to create a plasma in the source material for

emission of high energy photons and an apertured stop provided therebetween.

10

The use of the apertured stop, for example in the form of a skimmer plate, gives rise to

numerous advantages. Because the apertured stop collimates the beam, the debris

created is greatly restricted and also channelled away in the collimation direction from

the excitation component and collector i.e. collimation of the molecular beam is found

15   to restrict the flow of debris in the chamber to a narrow path. In turn this allows more

flexibility with the excitation component location and geometry. In a preferred

embodiment the excitation component comprises an electrical/magnetic excitation

component in which case the coil, plate or electrode configuration can be easily

varied.

20

Preferably the emitter emits source material at a supersonic velocity, yet further improving the channelling away of the beam from the excitation component as it takes place at high speed.

5   In addition EUV flux generation can be tuned at will into considerably more efficient conditions. In particular the volume/cross-section, velocity and density of the target gas stream can be varied over an extremely wide range to allow optimal efficiency of conversion to EUV radiation by altering the skimmer plate aperture dimensions appropriately.

10

The variable geometry also allows the size and shape of the EUV emitting volume to be controlled so as to match the requirements of the large collection optic, and the lithographic projection system which receives light from said optic.

15   Preferably the material emitter, which may be a nozzle, and excitation components are provided in separate chambers divided by the apertured stop. Accordingly the nozzle side of the chamber can be maintained at a high pressure and the pumping side at a very low pressure to restrict self absorption without the need for differential pumping. Even further, a greater proportion of the gas can be recirculated and

20   recycled.

8

Yet further, the gas beam provides a "sharp edge", having a fairly constant density across its cross-section. This is particularly advantageous in an alternative embodiment in which the excitation component comprises a laser pulse component as it ensures that laser power is not dissipated in a low density outer portion of the

5   molecular beam.

Further still, the excitation component does not have to be close to the nozzle to pump gas at an appropriate density – because the gas stream is collimated the excitation component can be located further downstream. This in turn further enhances

10   flexibility in design and configuration of the components.

Preferably the system further comprises a laser pre-ionisation element arranged to pre-ionise the source material stream prior to excitation by the excitation component. The laser pre-ionisation element may pre-ionises the source material stream at a

15   location upstream of the excitation component excitation region or at a point in time prior to, or during, excitation by the excitation component, preferably at the excitation component excitation region. The use of laser pre-ionisation preceding electrical/magnetic EUV generation allows the flexibility to create a range of pre-ionisation regimes which can be tailored for example to varying gas column diameters

20   and gas density, and makes use of the possibility of focussing the laser on all or a selected part of the gas beam, whether internal or external to the beam. Laser pre-ionisation is effective on a wide range of materials, and can easily and evenly pre-

9

ionise gas at any density again enhancing the flexibility of the system.. Because the
laser rise time is short, the focussed spot diameter controllable and the ionisation
behaviour highly reproducible, the pre-ionisation phase can be temporally and
physically very closely defined allowing the creation of conditions that are optimal for

5   subsequent excitation by electric or magnetic means and in particular fine control of
the pre-ionisation state, density and shape and pre-plasma temperature.

The laser focussing optic can be spaced further from the beam than a pre-ionisation
electrode, so reducing its exposure to the harsh environment created by the plasma.

10

Yet further it is found in practice that the coupling conditions in an electrical/magnetic
pumping scheme are especially suited to the pre-ionisation conditions generated by
laser pre-ionisation. Because the laser itself is non-intrusive the pre-ionisation pulse
can easily be focused at the same physical location as the electrical/magnetic

15   excitation which then effectively pumps the rapidly expanding pre-plasma created by
the laser pre-ionisation. A particular advantage of this is that pre-ionisation of the
target in the correct physical location can encourage the main discharge from
electrodes to travel directly to the plasma. This helps to avoid prestrikes or mis-strikes,
and might even be employed to prevent restrikes via further pulses or otherwise, by

20   channelling away the discharge in the same way that pulsed lasers can be used to
channel lightning strikes by pre-ionising a discharge channel through the atmosphere.

In combination these features which individually allow improved freedom in parameter variation give rise to a yet higher degree of flexibility. For example the pre-ionisation location is less constrained because of the use of a collimated beam of target gas.

5

According to a further aspect of the invention there is provided a high energy photon source comprising a source material emitter arranged to emit a stream of source material, an electrical or magnetic excitation component downstream thereof arranged to create a plasma in the source material for emission of high energy photons and a

10   laser pre-ionisation element arranged to pre-ionise the source material stream prior to excitation by the excitation component.

According to yet a further aspect of the invention there is provided a high energy photon source comprising a source material emitter arranged to emit a stream of

15   source material at supersonic velocity and an electrical or magnetic excitation component downstream thereof arranged to create a plasma in the source material for emission of high energy photons.

Embodiments of the invention will now be described, by way of example, with

20   reference to the drawings, of which:

Fig. 1 is a schematic view of a known LPP high energy photon source;

Fig. 2a is a schematic view of an improved high energy photon source;

Fig.2b is a schematic view of an electrical/magnetic high energy photon source according to the present invention;

Fig. 2c is a schematic view of an alternative preferred electrical/magnetic high energy photon source according to the present invention

Fig.3a shows a first pre-ionisation scheme;

Fig.3b shows a second pre-ionisation scheme;

Fig.3c shows a third pre-ionisation scheme;

Fig. 4 is a schematic view of an alternative electrical/magnetic high energy photon source according to the present invention;

Fig. 5. is a schematic view of an LPP high energy photon source according to the present invention; and

Fig. 6 is a plot of EUV conversion efficiency obtained according to the present invention.

Throughout the specific description, like reference numerals relate to like elements throughout the Figures, and explanation will be repeated only where appropriate.

Fig. 2a relates to an improved EUV source designated generally 10. Xenon is fed at high pressure through nozzle 12. The gas expands supersonically into a cone 14 on exiting the nozzle 12 and is subjected to electric/magnetic excitation by electrodes or

coils 16 which may in practice include induction coils or capacitative plates. In the

preferred version shown, the gas stream is pre-ionised by pre-ionisation coils 18.

The use of a supersonic molecular beam via a nozzle with electrical/magnetic pumping

5   and/or pre-ionisation formed by discharge, capacitative or inductive excitation of the

plasma and/or pre-plasma takes advantage of the high translational velocity of the gas

jet to remove debris from critical regions of the chamber and to avoid it impinging on

for example the collection mirror. However the gas conditions are only suitable for

electrical ionisation over a relatively narrow range of gas densities and geometries,

10   therefore limiting the range of conditions applicable for any subsequent major energy

deposition, and potentially restricting the parameterspace for the plasma to lower

efficiency conditions. The arrangement is provided in a chamber 20 and a pump 22 is

provided to allow differential pumping, but with disadvantages in the level of pumping

required to obtain an acceptable pressure differential across the chamber.

15

Referring now to Fig. 2b a preferred high energy photon source according to the

present invention includes the additional components of an apertured stop in the form

of a skimmer plate 26 comprising a partition across chamber 22 and a skimmer orifice

28 acting as a collimator having a converging frusto-conical flange 28a on its

20   downstream face. The gas cone 14 is incident on the skimmer plate and a central

column molecular beam 30 having a lower angle of divergence than gas cone 14 and

preferably being substantially parallel passes through the orifice 28, the remainder of

the gas being recirculated. The beam 30 is then pre-ionised by laser 32 and a plasma

is generated downstream between coils/electrodes 34. The plasma produces an EUV

flux as described above which is collected by collector 20. The nozzle side S1 of the

chamber 22 is maintained at a high pressure and the pumping side S2 at a very low

5   pressure to restrict self absorption via a pump (not shown). The collimated beam

allows improved efficiency of plasma generation and reduced debris and self-

absorption, as discussed above.

Referring to Fig. 2c it can be seen that the laser pre-ionisation pulse is focussed at the

10   same physical location 33 as the subsequent excitation pulse or field. In this case the

pre-ionisation pulse may precede the excitation pulse by a pre-determined period so

that the two steps are temporally rather than spatially separated. The timing of the

system is optimised such that maximum coupling is achieved by the excitation

component with the rapidly expanding pre-plasma generated by laser pre-ionisation.

15   This delay might even be reversed with the electrical switching starting just before the

laser. This allows time for the electric, magnetic field to build to a suitable level before

creating the receiving plasma. The size and density and ionisation state of the pre-

plasma formed by laser pre-ionisation can of course be controlled by appropriate

optics. The non-intrusive nature of laser pre-ionisation provides clear advantages in

20   flexibility of location of pre-ionisation as a result.

An example of this can be seen in the data of Fig 6. In this figure the yield of EUV
radiation at 13.5 nm is shown as a function of laser pre-ionisation excitation density.
The peak of the graph corresponds to a plasma temperature which is optimum for
EUV generation at this wavelength. Either side of the peak are hotter and cooler

5   plasma temperatures. This demonstrates the inherent flexibility of laser pre-ionisation
in choosing the ionisation state of the plasma yet retaining even ionisation conditions.

Further advantages of laser pre-ionisation can be understood with reference to Figs. 3a
to 3c. Three exemplary pre-ionisation schemes are shown in a beam 30. In Fig. 3a the

10   laser is focussed on a peripheral part 31a of the beam.. In Fig. 3b the laser is focussed
across the beam cross-section, in an essentially circular spot, and in Fig. 3c a linear
portion of the beam is pre-ionised. In each case it will be appreciated that the pre-
ionisation pulse will be timed such that the pre-ionised portion of the beam will reach
the main electrodes/coils 34 at the moment these are energised for optimum plasma

15   creation efficiency. This includes pre-ionisation created spatially within the
electrodes/coils as in Fig. 2c. Again as discussed above improved flexibility in system
design is thus allowed.

Indeed a further variant is shown in Fig. 4 in which the skimmer plate is dispensed

20   with and laser pre-ionisation is provided using laser 38 upstream of
electrical/magnetic excitation coils/electrodes 14 or (not shown) spatially local as in
Fig. 2c, providing once again the advantages of laser pre-ionisation discussed above.

15

It will be appreciated, however, that the system will also operate with a skimmer plate but no pre-ionisation. An alternative, LPP configuration according to the present invention is shown in Fig.5. In this arrangement the electrodes 34 are replaced by a

5   laser pump 36 together with appropriate optics (not shown), as a result of which pre-ionisation is not required in the preferred embodiment. It will be appreciated that the LPP pumping scheme shown in Fig. 5 can equally be replaced with an electrical/magnetic pump such as that shown in Figs. 2a to 2c.

10   The nature, construction and materials of the individual components of the system will be well known to the skilled person and the ranges that follow are exemplary rather than limiting. The source gas is preferably an inert gas such as Xenon although any other appropriate gas may be used, together with a buffer gas such as Helium. According to the best mode presently contemplated the gas is introduced at a pressure

15   in the range 1-50 bar through a nozzle aperture in the range 0.1 – 0.4mm into the high pressure side S1 of the chamber 22 which is maintained at a pressure 0.02 – 100 mbar. The skimmer aperture is in the range 0.1 to 20mm with flange angle between 2-45°. The collimated beam 30 enters the low pressure side S2 of the chamber 22 at a pressure in the range 10^{-4} – 10 mbar with a divergence angle in the range 4-45° and a

20   beam diameter in the range 0.3 to 3mm. The low pressure side S2 of the chamber 22 is maintained at a pressure in the range 10^{-4} – 10^{-8} mbar. The various pressures can be maintained using pumps of any appropriate kind.

16

The electrodes/coils used can be of any suitable type or configuration suitable for
discharge, capacitative or inductive heating/excitation of the plasma. The lasers used
either in pre-ionisation or for LPP can be of any appropriate type, for example gas

5   lasers, excimer lasers or solid state lasers. The pre-ionisation laser pulse preferably
has a rise time in the range 0.2ns – 100 ns and pulse duration between 1ns and 1000ns.
In the LPP scheme the laser preferably has a repetition rate in the range 1-100kHz.

It will be appreciated that various aspects of the different embodiments can be altered

10   or interchanged as appropriate. For example the skimmer plate can be used in either
the electrical/magnetic excitation or LPP scheme with or without pre-ionisation, or
indeed with only electrical pre-ionisation, or the skimmer plate can be dispensed with
under laser pre-ionisation. Any appropriate gas can be used and need not necessarily
be inert. Indeed the system could be applied to a liquid source material beam;

15   although beam collimation may be less of an issue in such circumstances. Although
the discussion above is directed to use of a skimmer plate, the use of any appropriate
apertured stop or collimating means is contemplated.

Claims

1. A high energy photon source comprising a source material emitter arranged to
    emit a stream of source material, an excitation component downstream thereof
    arranged to create a plasma in the source material for emission of high energy
    photons and an apertured stop provided therebetween.

2. A source as claimed in claim 1 in which the apertured stop comprises a
    skimmer plate.

3. A source as claimed in claim 1 or claim 2 in which the emitter emits source
    material at a supersonic velocity.

4. A source as claimed in claim 1 in which the material emitter and excitation
    component are provided in separate chambers divided by the apertured stop.

5. A source as claimed in any preceding claim in which the excitation component
    comprises an electrical/ magnetic excitation component.

6. A source as claimed in claim 5 further comprising a laser pre-ionisation
    element arranged to pre-ionise the source material stream prior to excitation
    by the excitation component.

18

7. A source as claimed in claim 6 in which the laser pre-ionisation element pre-ionises the source material stream at a location upstream of the excitation component excitation region.

8. A source as claimed in claim 6 in which the laser pre-ionisation element pre-ionises the source material stream at a point in time prior to excitation by the excitation component.

9. A source as claimed in claim 8 in which the laser pre-ionisation element pre-ionises the source material stream at the excitation component excitation region.

10. A source as claimed in any of claims 1 to 4 in which the excitation component comprises a laser pulse component.

11. A high energy photon source comprising a source material emitter arranged to emit a stream of source material, an electrical or magnetic excitation component downstream thereof arranged to create a plasma in the source material for emission of high energy photons and a laser pre-ionisation element arranged to pre-ionise the source material stream prior to excitation by the excitation component.

12. A source as claimed in claim 11 further comprising a skimmer plate provided between the emitter and the excitation component.

13. A source as claimed in claim 11 or 12 in which the laser pre-ionisation element pre-ionises the source material stream at a location upstream of the excitation component excitation region.

14. A source as claimed in claim 11 or 12 in which the laser pre-ionisation element pre-ionises the source material stream at a point in time prior to excitation by the excitation component.

15. A source as claimed in claim 14 in which the laser pre-ionisation element pre-ionises the source material stream at the excitation component excitation region.

16. A high energy photon source comprising a source material emitter arranged to emit a stream of source material at supersonic velocity and an electrical or magnetic excitation component downstream thereof arranged to create a plasma in the source material for emission of high energy photons.

17. A high energy photon source substantially as herein described and as illustrated in any of Figs. 2 to 5 of the drawings.

FIG. 1

FIG. 2a

FIG. 2b

FIG. 2c

FIG. 3a


FIG. 3b

FIG. 3c

FIG. 4
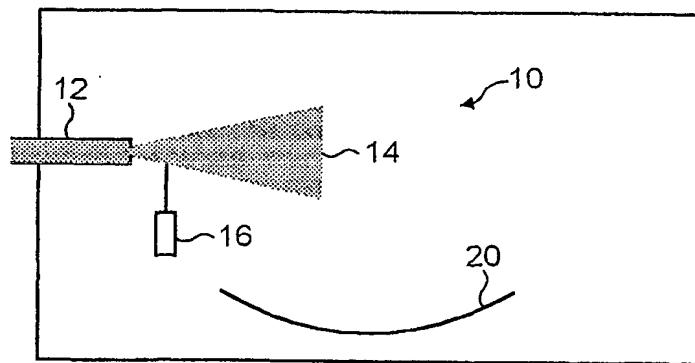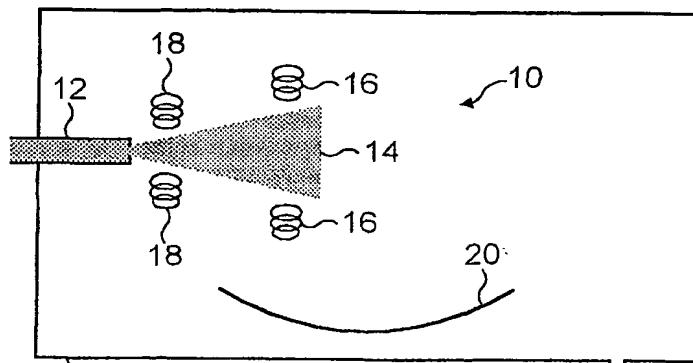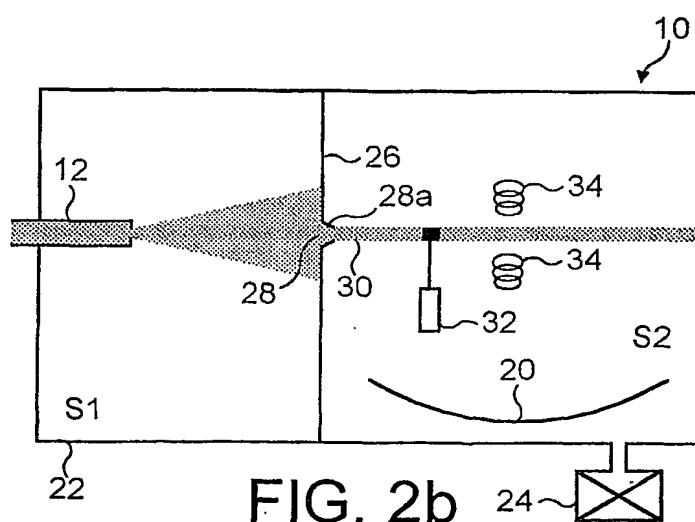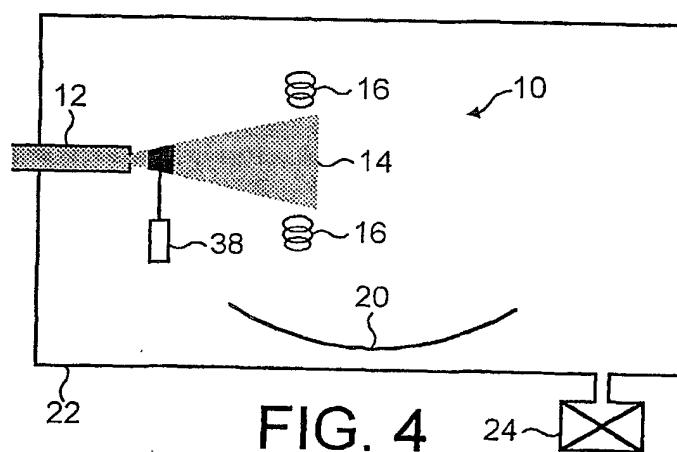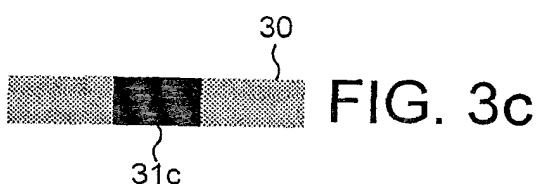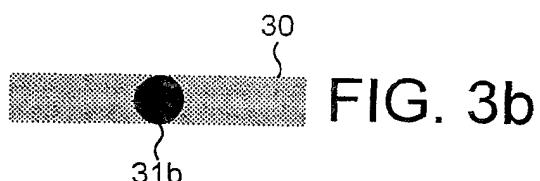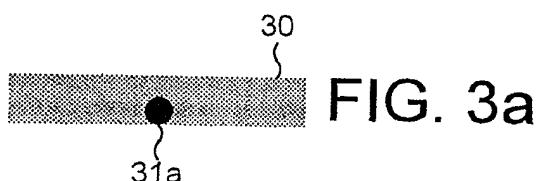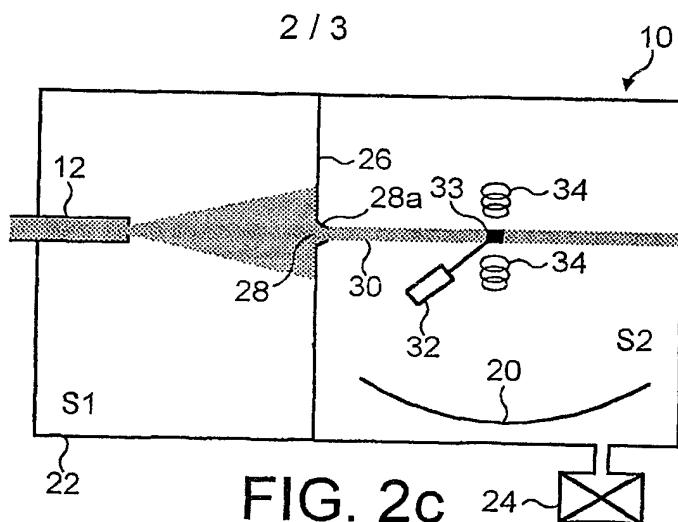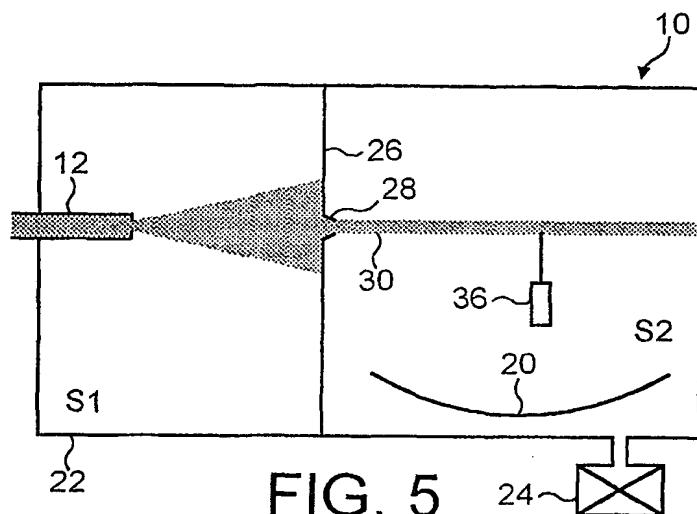
FIG. 5

FIG. 6

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7   H05G2/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7   H05G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	BERGMANN K ET AL: "HIGHLY REPETITIVE, EXTREME-ULTRAVIOLET RADIATION SOURCE BASED ON A GAS-DISCHARGE PLASMA" APPLIED OPTICS, OPTICAL SOCIETY OF AMERICA, WASHINGTON, US, vol. 38, no. 25, 1 September 1999 (1999-09-01), pages 5413-5417, XP000854494 ISSN: 0003-6935 figure 1	1,17

A	US 6 084 198 A (BIRX DANIEL) 4 July 2000 (2000-07-04) cited in the application abstract column 10, line 12 - line 47	1

	-/--	

[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

22 July 2002

Date of mailing of the international search report

24/10/02

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Oestreich, S

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 01 49087 A (KONINKL PHILIPS ELECTRONICS NV) 5 July 2001 (2001-07-05) abstract	1
A	WO 98 34234 A (NORTHROP GRUMMAN CORP) 6 August 1998 (1998-08-06) abstract	3

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 6084198	A	04-07-2000	US	5866871 A	02-02-1999
			US	6300720 B1	09-10-2001
			US	6172324 B1	09-01-2001
			EP	1015161 A1	05-07-2000
			WO	9848973 A1	05-11-1998
WO 0149087	A	05-07-2001	WO	0149087 A1	05-07-2001
			EP	1157597 A1	28-11-2001
			US	6304630 B1	16-10-2001
WO 9834234	A	06-08-1998	US	6133577 A	17-10-2000
			EP	1016092 A1	05-07-2000
			JP	2001511311 T	07-08-2001
			WO	9834234 A1	06-08-1998

INTERNATIONAL SEARCH REPORT

Box I	**Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II	**Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

   1-10,17

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (1)) (July 1998)

FURTHER INFORMATION CONTINUED FROM   PCT/ISA/ 210

This International Searching Authority found multiple (groups of)
inventions in this international application, as follows:

1. Claims: 1-10, 17

   High energy photon source comprising an apertured stop
   between material emitter and excitation component.
   Remark: Claim 17 inadmissible, Rule 6.2 (a) PCT.

2. Claims: 11-15

   High energy photon source comprising an electrical and
   magnetic excitation means and laser preionisation element.

3. Claim : 16

   A high energy photon source comprising a material emitter
   arranged to emit material at supersonic velocity combined
   with electrical or magnetic excitation means.